NOAA Chemical Modeling Workshop

Global Aerosol Forecasting and Data Assimilation in GFS/GSI

Overview and Progress*

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The long-term goal

Where we stand now

Ongoing and near-future activities

Global model with explicit ozone-aerosol chemistry

Parameterized ozone chemistry and climatological aerosol scheme

Incorporate prognostic aerosols in global model

Radiance assimilation providing meteorological and chemical analyses

SBUV/2 v6 ozone assimilation; background aerosols assumed

Assimilation of multiple ozone products; aerosol module added to radiative transfer model

Provide meteorological and chemical LBCs for the regional system

Improved chemical LBCs are needed for regional AQ application

Off-line and Lagrangian chemistry modeling

NCEP Global Aerosol Forecasting and Data Assimilation

- **OVERVIEW**
  - Create an integrated operational system for forecasting and monitoring the atmospheric dynamics and chemistry
- **OBJECTIVES**
  - Generate an optimal (accurate and affordable) description of the global distribution of atmospheric aerosols
  - Provide improved air-chemistry forecasts, through improved use of satellite data
  - Respond to the WMO RSMC request for global dust predictions and to NWS/HQ and EPA request for improved aerosol LBCs for CMAQ

NCEP Global Aerosol Forecasting and Data Assimilation (-continued)

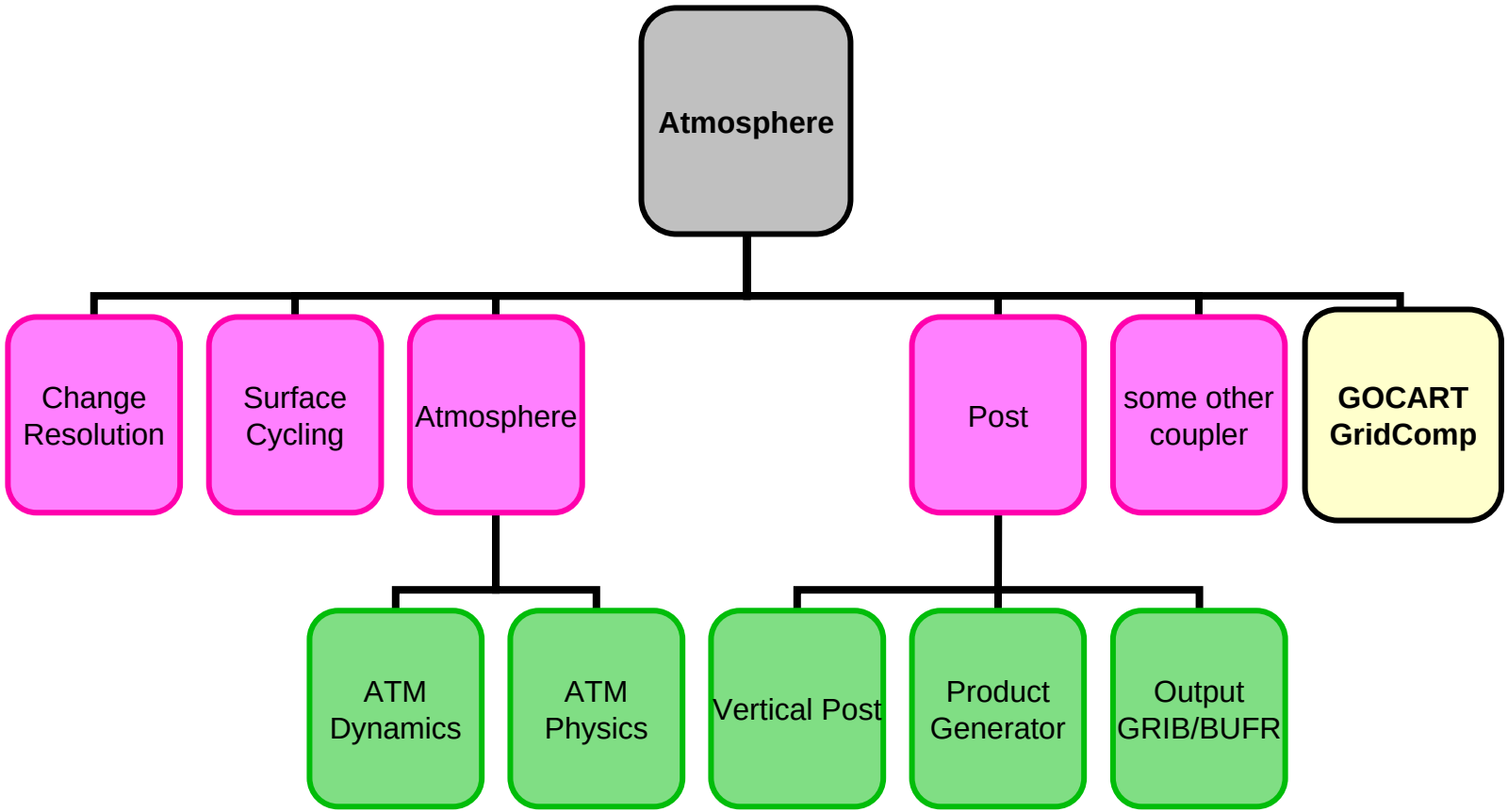
- **APPROACH**
  - Incorporate prognostic aerosols (NASA GOCART) in NCEP Global Forecast System (GFS)
    - Off-line non-interactive
    - In-line interactive
  - Assimilate aerosol measurements (product and then radiance) in NCEP Gridpoint Statistical Interpolation system (GSI)
  - Leverage common modeling framework and shared software development
    - Earth Systems Modeling Framework **(ESMF)**
    - Joint Center for Satellite Data Assimilation **(JCSDA)**

Global Forecast System (GFS)

Global spectral model for operational medium range forecasts

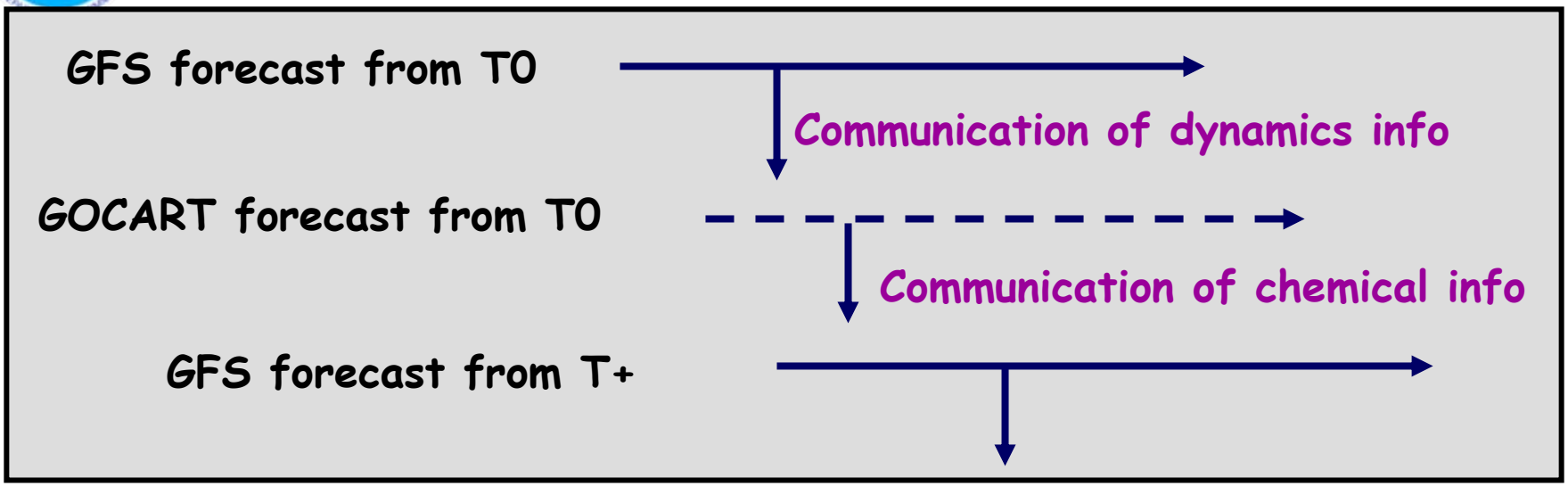
- **RESOLUTION**
  - T382 horizontal resolution (~ 37 km)
  - 64 vertical levels (from surface to 0.2 mb)
- **MODEL PHYSICS AND DYNAMICS**
  - Vertical coordinate changed from sigma to hybrid sigma-pressure
  - Non-local vertical diffusion
  - Simplified Arakawa-Schubert convection scheme
  - MD Chou radiation scheme
  - Explicit cloud microphysics
  - Noah LSM (4 soil layers: 10, 40, 100, 200 cm depth)
- **INITIAL CONDITIONS** (both atmosphere and land states)
  - NCEP Global Data Assimilation System (GDAS)

Earth System Modeling Framework (ESMF) Component Framework

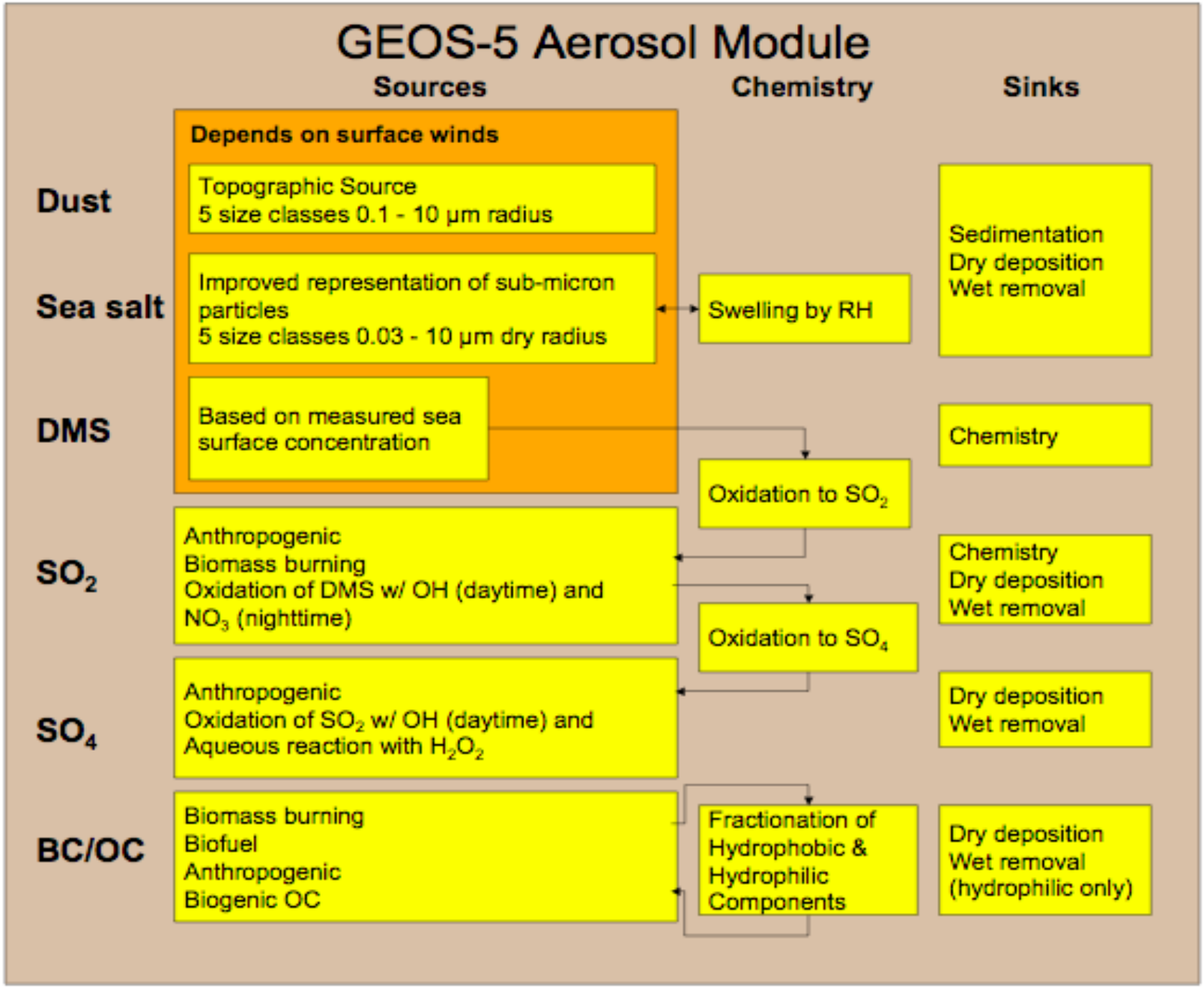


Mark Iredell (NCEP)

Prototype aerosol forecasting system



- Gridded GFS (under development):
  - Determine aerosol transport processes (advection, boundary layer turbulent mixing and convective transport)
  - Export dynamical info (surface wind, humidity, and canopy conductance…etc) to GOCART grid component
- GOCART grid component:
  - Determine aerosol source, sink, transformation
  - Export updated distributions of aerosol species to gridded GFS



Collaborator: Mian Chin, Code 613.3

Gridpoint Statistical Interpolation (GSI)

Global/regional analysis system for operational weather forecasts

- **NCEP 3DVAR assimilation system**
  - Implemented with WRF-NMM into the NAM system in June, 2006
  - Implemented for replacement of SSI in the GFS system in May, 2007
- **SCIENTIFIC ADVANCES**
  - Grid point definition of background errors
  - Inclusion of new types of data (e.g., AIRS radiance, COSMIC GPS)
  - Advanced data assimilation techniques (e.g., improved balance constraints)
  - New analysis variables (e.g., SST)
- **CODE DEVELOPMENT**
  - GSFC/GMAO collaboration through JCSDA
  - Evolution to ESMF

Community Radiative Transfer Model (CRTM)

- The Community Radiative Transfer Model is developed via joint effort of JCSDA (from contributions from NOAA, NASA, and DOD), research institutions and private companies.
- The CRTM is composed of advanced surface emission and reflection models, fast gaseous absorption models, aerosol and cloud optical modules.
- It is used in GSI for global and regional data assimilation as well as applied in GOES-R studies.
- The aerosol module contains the mass extinction, scattering coefficients and detailed phase function for dust, sea salt, organic carbon, black carbon, and sulfate with various effective particle sizes.
- The CRTM fully supports aerosol radiance assimilation for the GFS-GOCART system.

Aerosol Data Assimilation

- Goal: Configure an aerosol assimilation system with the flexibility to incorporate assimilation techniques of varying complexity and the extensibility for the inclusion of additional current or future aerosol instruments
- Planned phased deployment:
  - Incorporation of GOCART prognostic aerosols into GFS
  - Refinement of the GFS-GOCART modeling system
  - Benchmark studies of global aerosol simulations
  - Incorporation of aerosol module into CRTM
  - Estimations of background errors (using NMC method)
  - GSI modification for aerosol assimilation
    - Univariate assimilation of MODIS aerosol retrievals
    - Multi-variate assimilation including aerosol sensitive channels (jointly assimilation of MODIS/OMI radiance)

Data Availability

- NCEP is receiving MODIS level 1 product and OMI AI in real time
- GOES column integrated AOD product is available
- Potential data sources
  - OMI-like aerosol retrievals produced by the GOME-2, UV+ VIS
  - AIRS (Advanced Infrared Radiation Sounder), IR
  - MLS (Microwave Limb Sounder), stratospheric aerosol, MW
  - Future Sensors: GOES-R ABI, NPOESS VIIRS, CrIS, OMPS
- Challenges:
  - Inability of satellite retrievals to identify aerosol specification and vertical structure

Conclusions

- NCEP recently initializes the efforts to develop global aerosol forecasting and assimilation capability in GFS/GSI via the NCEP-GSFC collaborations.
- This project will enable the use of NASA earth science results (GOCART model and MODIS/OMI measurements) to enhance NOAA environmental forecasting capability.
- Logistics for research-to-operation
  - Resources:
    - R& D efforts needed to add new analysis variables in GSI
    - The number of transported tracers increases from 3 to 21
  - Communication path (NRT)
  - Data format (BUFR)
  - Operation transition protocol

Thank You

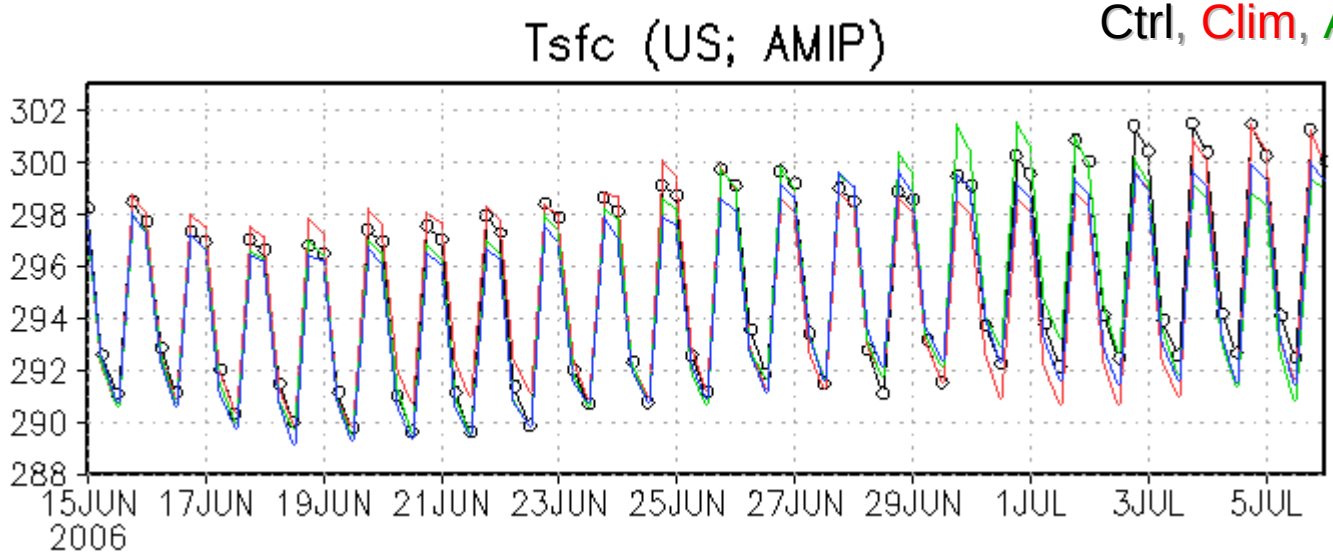
Back-ups

GFS Sensitivity Study

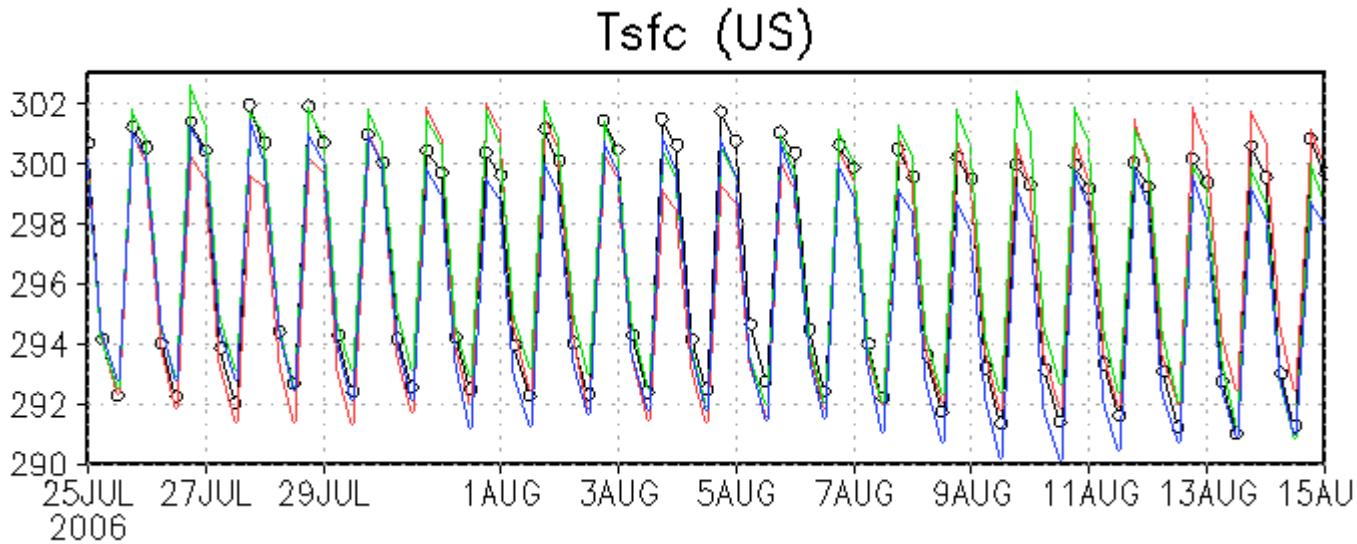
- T126 L64, hybrid coordinate
- AMIP experiment
  - Initialized from 2006-06-01 00Z GDAS analysis
  - 11-week integration (edate = 2006-08-15)
- MRF experiment
  - Initialized from 00Z analysis for the 2006-06 period
  - 5-day forecasts
- Aerosol scheme configuration
  - CTRL: OPAC climatological scheme
  - CLIM: GOCART climatological scheme
  - ANAL: Diagnostic aerosols updated daily
  - PROG: Aerosols as passive tracers updated every 6-hr
- The CLIM run uses GEOS3-GOCART monthly climatology (M. Chin); the ANAL and PROG runs use GEOS4-GOCART 6-hr aerosol analysis (A. da Silva).
- A fully cycled GDAS experiment is in progress to assess the impact of aerosols on GFS forecasts

Time series of Tsfc

Ctrl, Clim, Anal, Prog



Wk 3-5

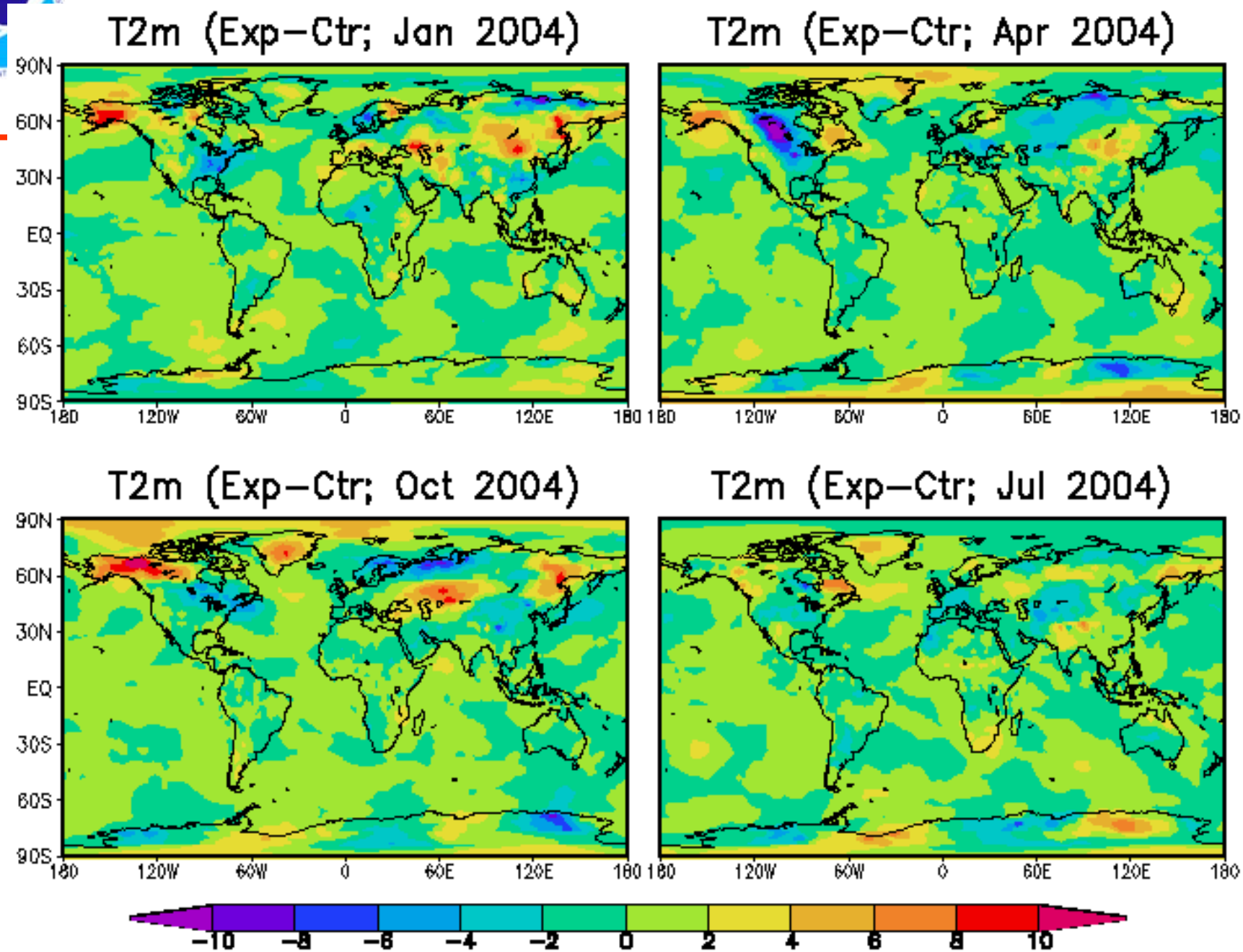


Wk 9-11

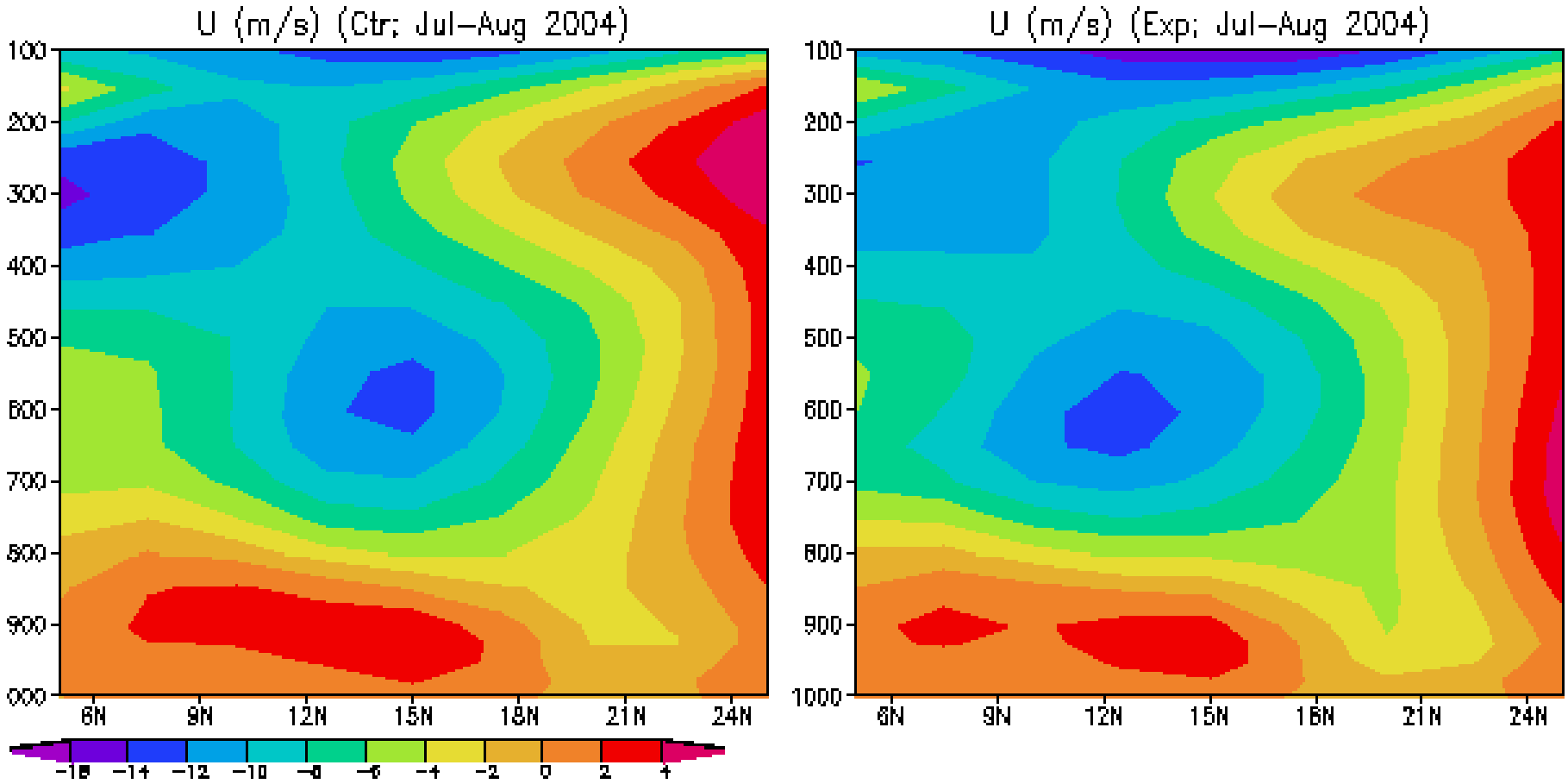
Preliminary CFS results

- **NCEP Climate Forecast System (CFS)**
  - AGCM : GFS
  - Ocean model: GFDL MOM3
- **CFS experiments**
  - 3-year runs (from 2002/01 to 2004/12)
  - Resolution: T126 L64
  - Output every 6 hr
  - Two runs:
    - Ctr: OPAC-based aerosol climatology (5º x 5º)
    - Exp: GOCART aerosol fields (2.5º x 2º; 30 lvl)
- The global impact and regional influence due to different background aerosol loading are examined.

T2m Difference

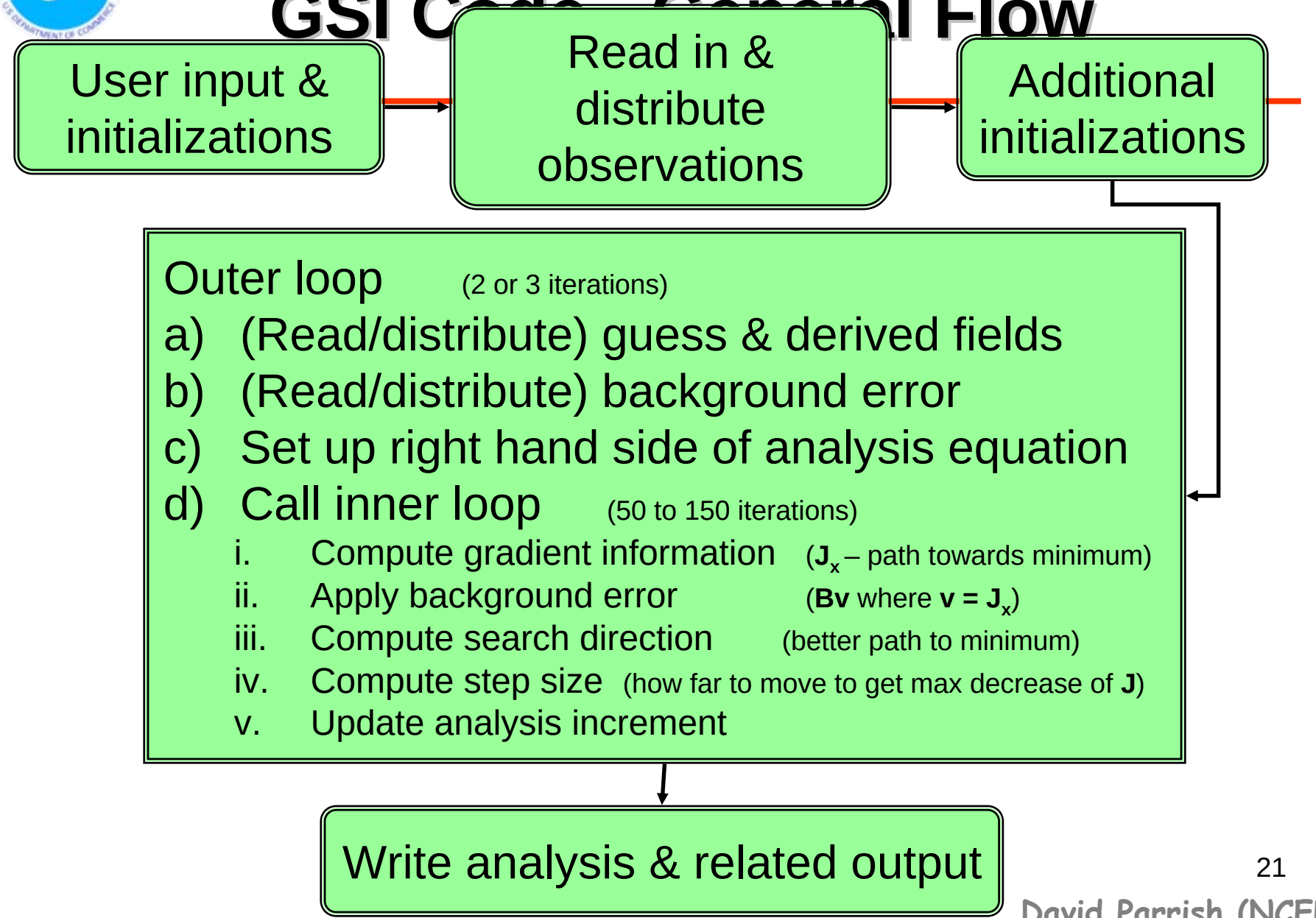


U-wind Cross Section at 10W

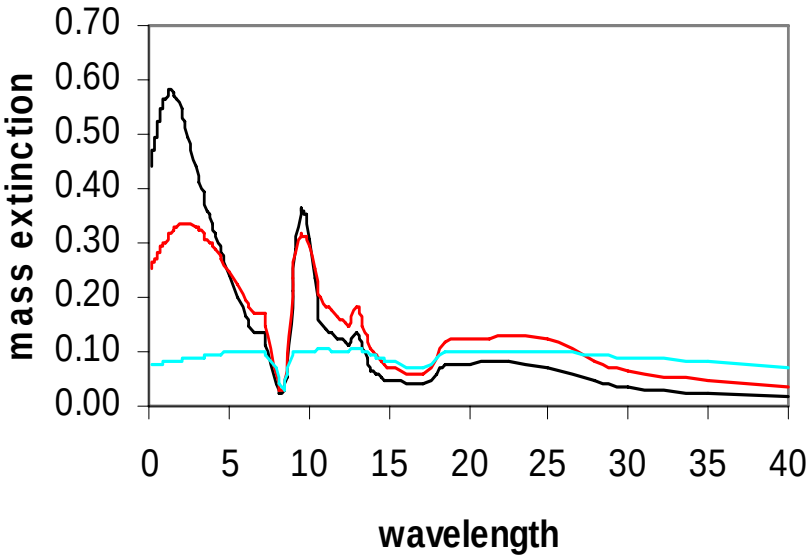


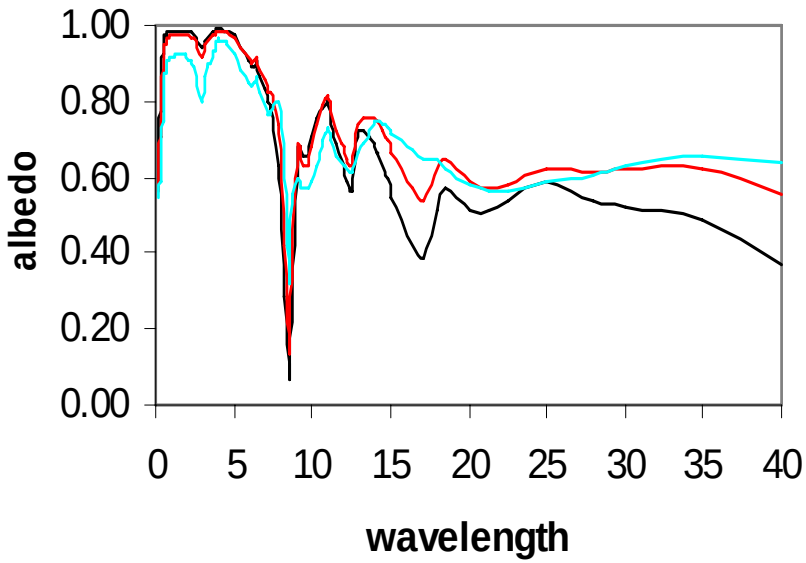
The intensity and location of African Easterly Jet are affected by background aerosol loading (via direct radiative effect)

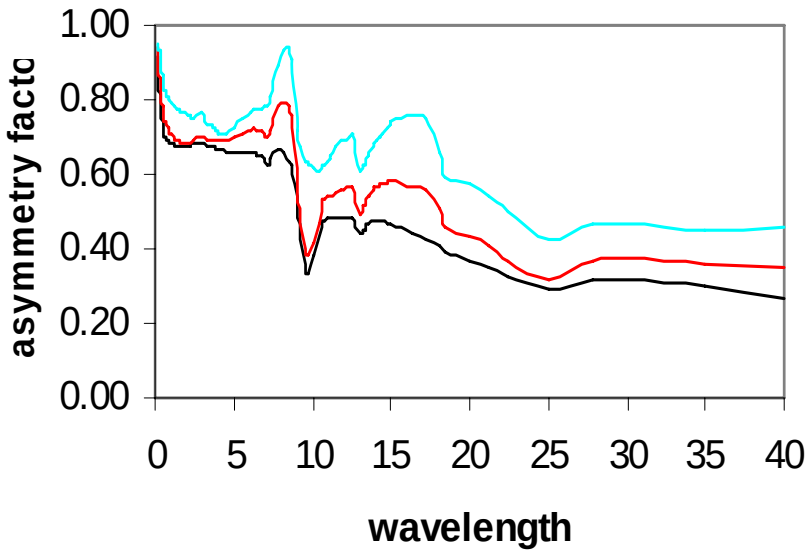
GSI Code – General Flow



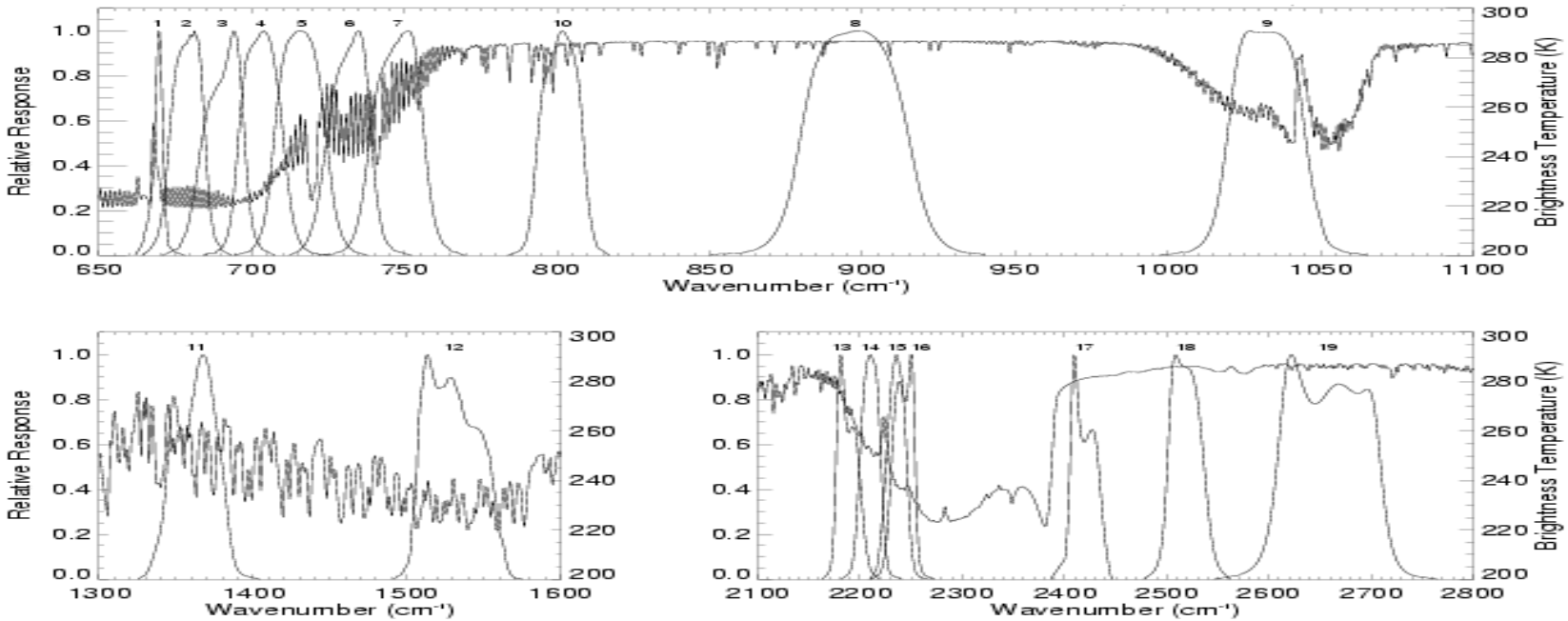
Aerosol Optical Properties -- Dust aerosols







Aerosol effects on hirs3_n17



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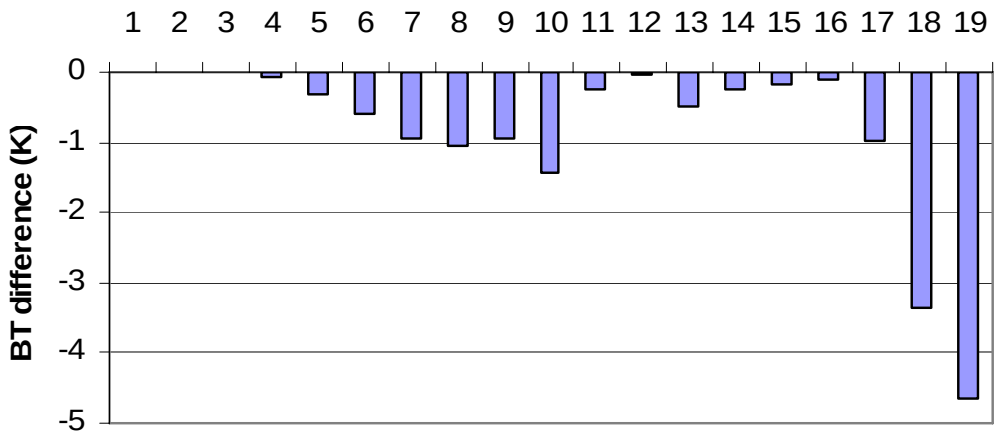


No clouds

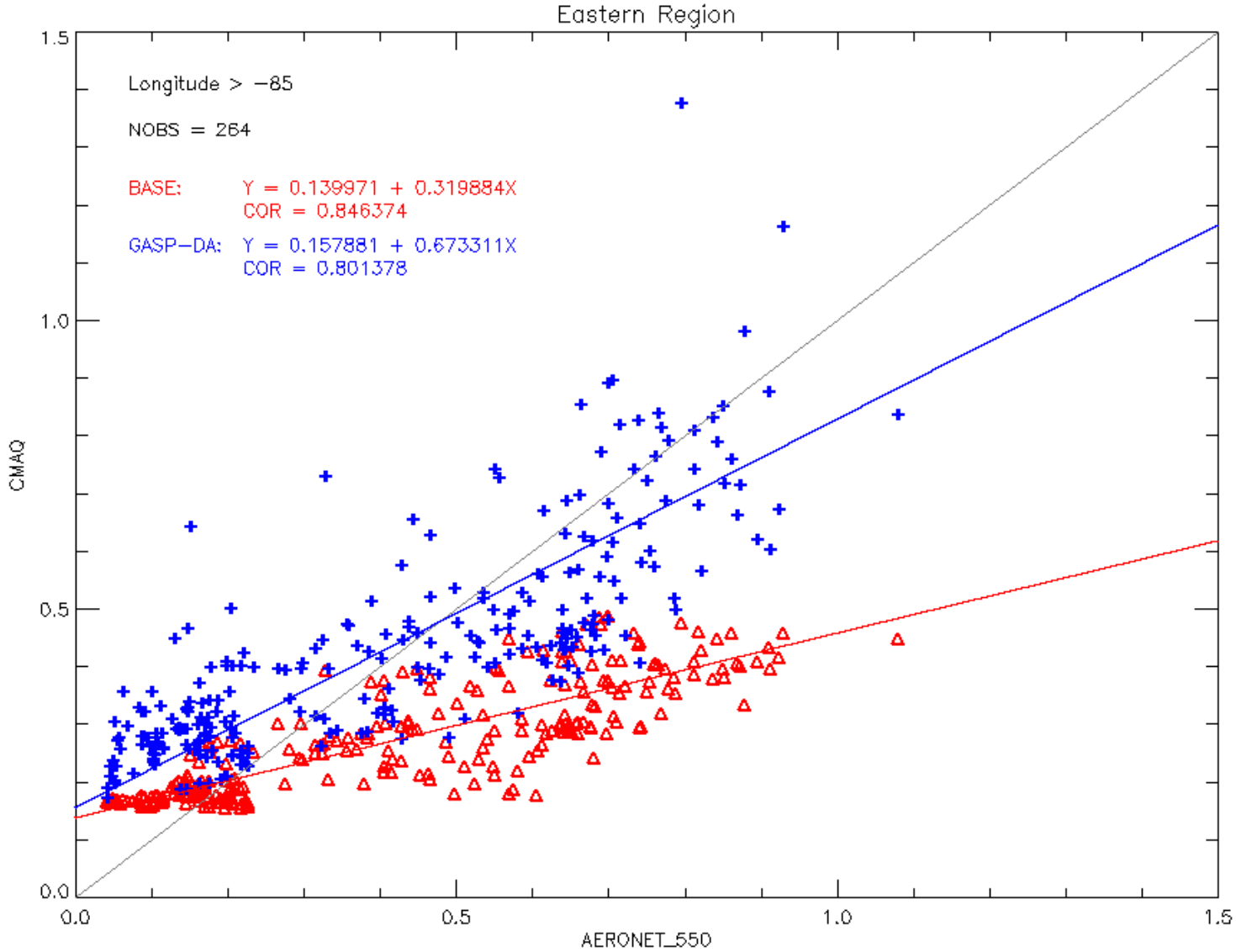
0.1 g/m2 OC aerosol at 300 hPa

0.1 g/m2 Dust aerosol at 600 hP

0.1 g/m2 Dust aerosol at 650 hP

Quanhua Liu (JCSDA)

10-day CMAQ simulations
Base run vs assimilation run using GOES



S. Kondragunta & Q. Zhao (NESDIS)

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Discussions

- Chemical data assimilation using GSI are in progress or planned. These include but are not limited to:
  - OMI total and profile ozone assimilation (G. Long, CPC)
  - MLS ozone data assimilation (I. Stajner, GSFC)
  - Regional ozone assimilation for WRF-CHEM (G. Grell, OAR-GSD)
  - Regional GOES ozone assimilation for UH-CMAQ (B. Pierce, NESDIS-CIMMS)
  - Aerosol data assimilation for CMAQ (S. Kondragunta, NESDIS-ORA)